Proofs of non-stomatal limitations of potato photosynthesis during drought by using eddy covariance data

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Objectives

- To infer ecosystem physiological proprieties from eddy covariance data at the canopy level.
- To evaluate wether a reduction in potato photosynthesis during drought originates from a strict stomatal control (SOL) or from non-stomatal limitations (NSOL).

Methodology

Classic post processing treatments for EC data.

- SOL : canopy sensitivity to photosynthesis G_1 with the Medlyn et al. model (Medlyn et al., 2011) (Eq. 1). Use of the Penman-Monteith equation (Penman, 1948) to determine G_c.
- NSOL : apparent maximum carboxylation rate V_{cmax} (Eq. 2) (Arneth et al., 2002).
- Sensitivity analysis : quantification of the bias induced by the non-inclusion of water stress influence in the parametrization of V_{cmax} and G_1 : calculation of ratios between GPP modelled by using unstressed V_{cmax} and G_1 values, and measured GPP (GPP_{Vcmax}*/GPP and GPP_{G1}*/GPP) (Zhou et al., 2013).

Quality controls for G_1 and V_{cmax} calculations : PPFD (1200 µmol.m-2.s-1), surface wetness, phenology and statistic filters (Knauer et al., 2018).

REW was daily computed by weighting the water availability of each soil layer by its height up to the maximum root depth (Eq. 3), modelled with the Hartmann et al. (2017) model. Breakpoints were determined by using segmented linear regressions.

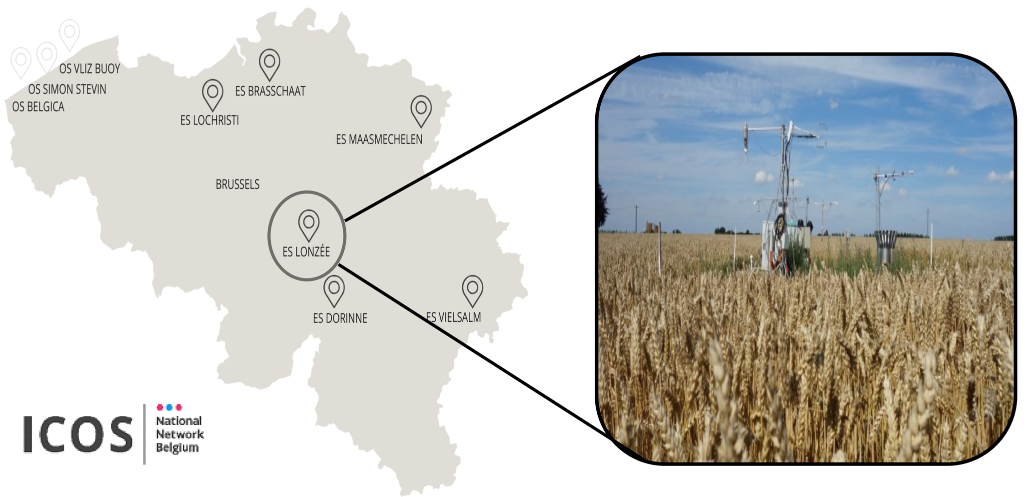
(1) $$G_c = 1.6\left(1+\frac{G_1}{\sqrt{VPD}}\right)\frac{GPP_{sat}}{C_a}$$

(2) $$V_{cmax} = \frac{GPP_{sat}(C_i+K_m)}{C_i-\Gamma^*}$$

(3) $$REW = \frac{\sum_{surf}^{root\ depth} SWC - SWC_{wp}}{\sum_{surf}^{root\ depth} SWC_{fc} - SWC_{wp}}$$

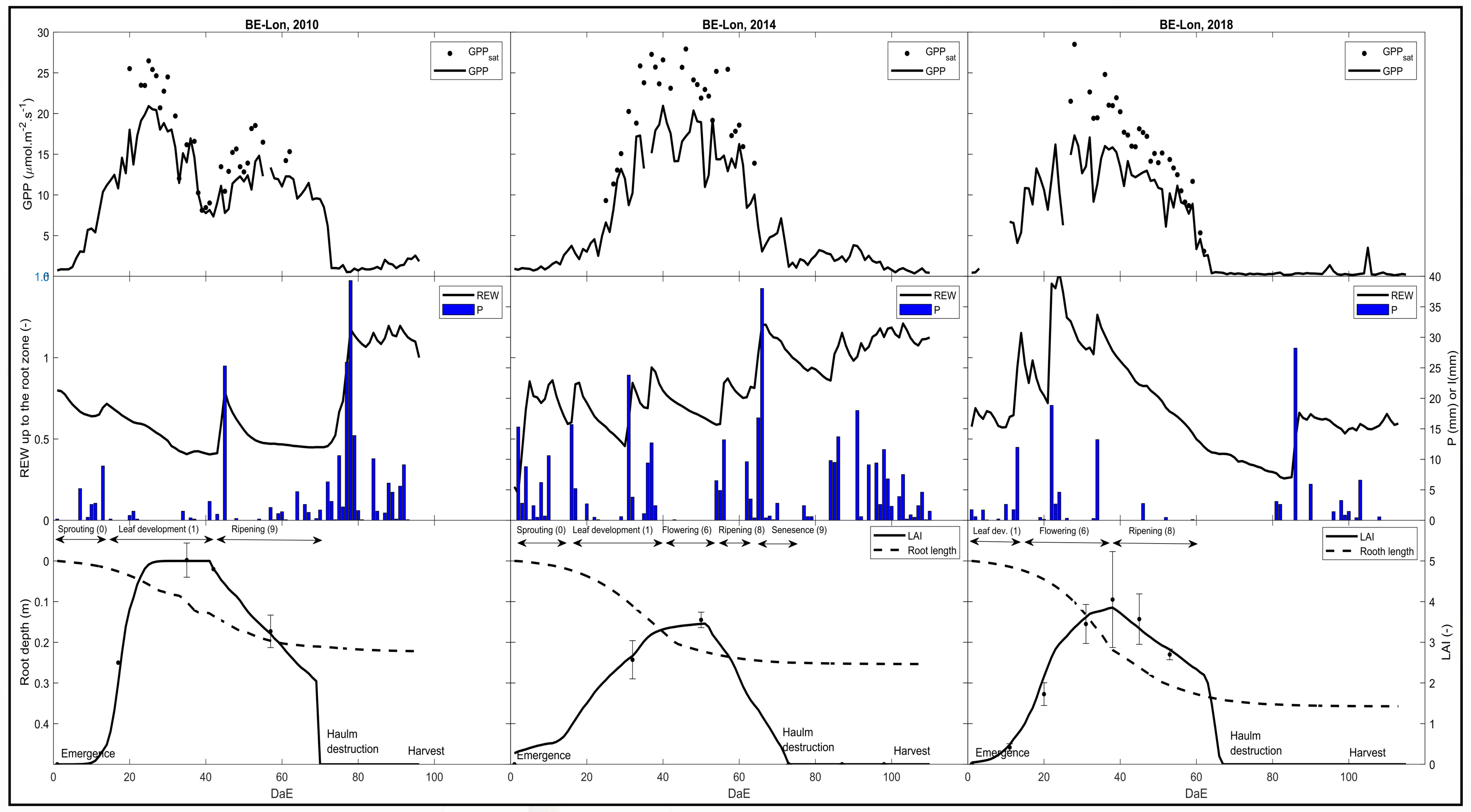
Site : BE-Lon

- Production crop : 4 years roation typical of Belgium including seed potatoes
- Soil water content measured at five depths (5, 15, 25, 55 and 85 cm)



Results

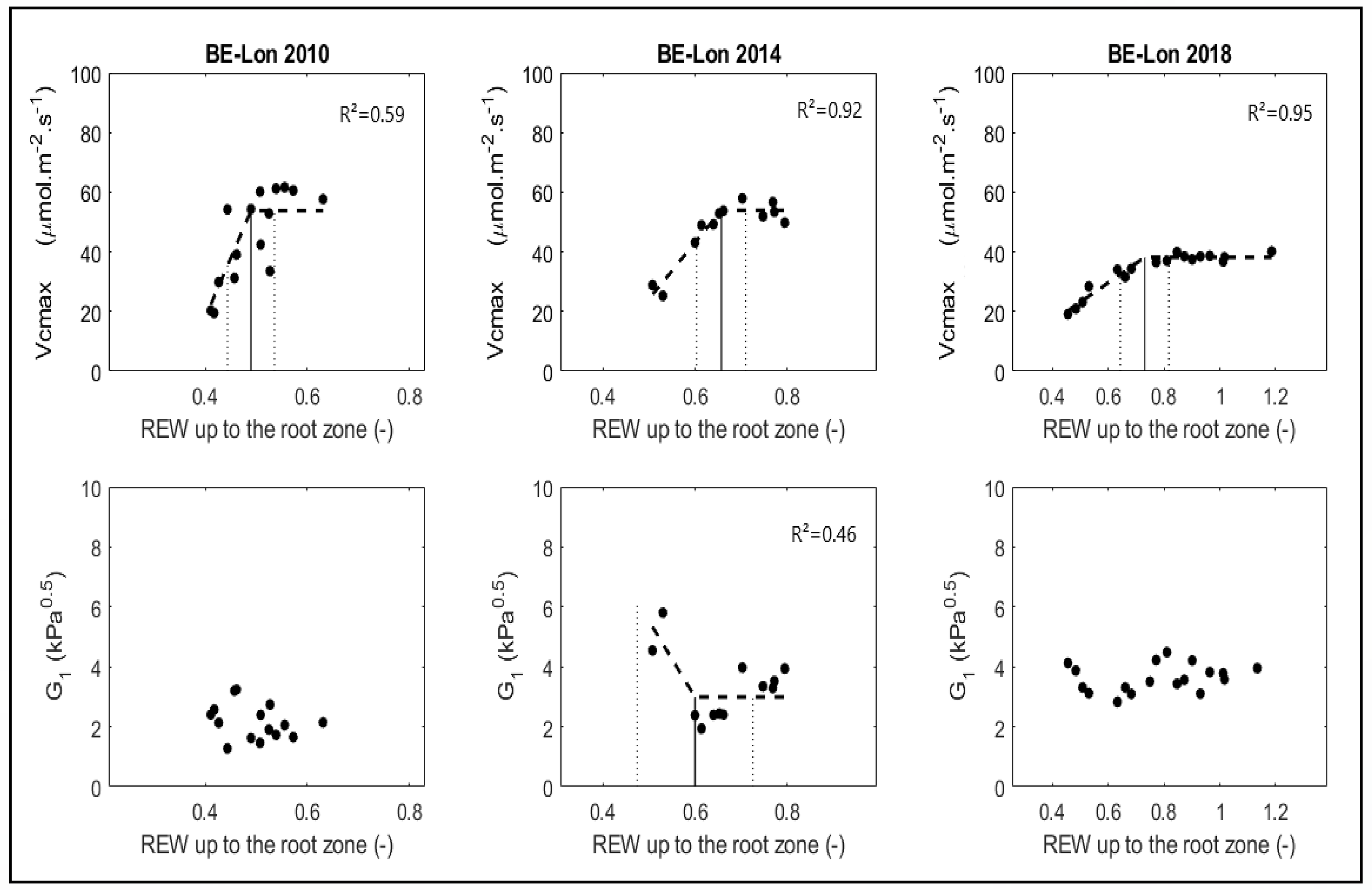
1. Pedo-climatic conditions and crop dyna-



⇒ **GPP anomalies** recorded in 2010 (leaf development stage), 2014 and 2018 (ripening stage). **Synchronized** dynamics with **REW** and **lack of precipitation**.

⇒ 2018 was the driest year, in terms of precipitation deficit and low soil water availability.

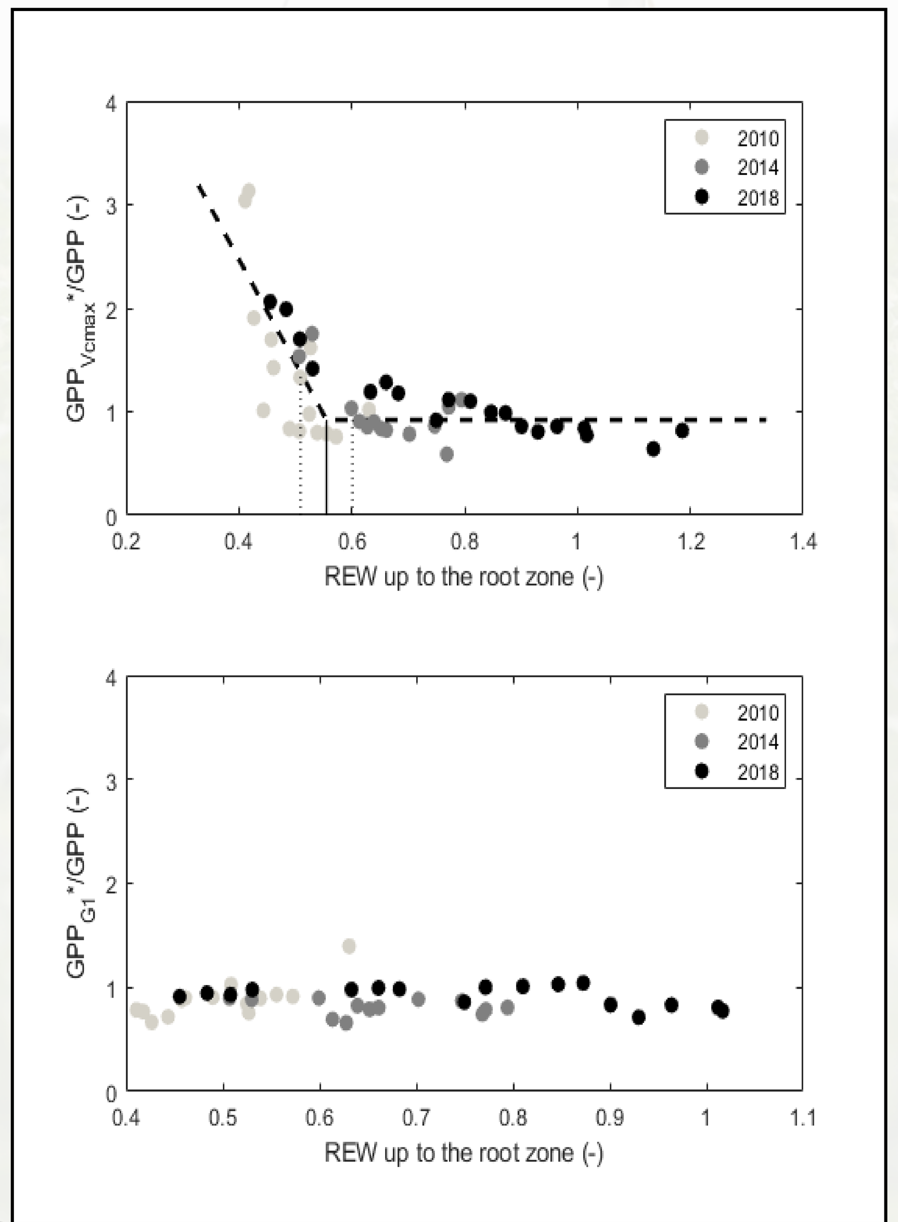
2. Impact of drought on SOL and NSOL



⇒ **G_1 remained constant** while **V_{cmax} decreased** from a REW breakpoint. The slight increase in G_1 in 2014 might be attributed to high Ci due to low apparent Vcmax values.

⇒ Narrow ranges of REW breakpoints

3. Impact on GPP modelling



⇒ **GPP** was **overestimated** compared to its corresponding unstressed value when drought wasn't taken into account in V_{cmax} paramterization.

⇒ **No matter the years, NSOL were the dominant mechanism** of photosynthesis control when soil water availability decreased by 45 % **(REW = 0.55 ± 0.05)**

⇒ Discrepancy between « optimal » stomatal behaviour (decrease of G_1) and our results: need of a revision of the cost associated with the opening of stomata.

!! Take home message !!

- NSOL were the dominant mechanism limiting photosynthesis during drought.
- REW = 0.55 ± 0.05 could be used as a relevant threshold for crop modelling.
- Revaluation of the cost of the opening of stomata.

What's next ?

- How important is the mesophyll constrain ?
- Use of fluorometry and gas exchange measurements to infer g_m.
- Complete overview of photosynthetic flux limitations during drought.